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NOTES OF A PRELIMINARY EXAMINATION OF PHOTOGRAPHS OF *JUPITER* TAKEN AT THE LICK OBSERVATORY IN 1891.

By A. Stanley Williams, F. R. A. S.

The Royal Astronomical Society has lately been presented with an extensive collection of original negatives of *Jupiter* taken at the Lick Observatory in 1891. The notes which follow are the results of a preliminary examination of these negatives and of a series of positive copies on glass, which, through the courtesy of Professor Holden, the writer was enabled to make of this magnificent collection. Astronomers on this side of the Atlantic should be greatly indebted to the authorities of the Lick Observatory for thus placing at their disposal such an extensive and valuable series of original photographs. The most perfect collection is, naturally, still preserved at the Lick Observatory itself, but in presenting as complete a set of duplicate negatives as possible to a suitable central station, an example is given worthy of being extensively followed. Photographs, however valuable in themselves, are of little use unless they are properly examined and studied, and the resources of few observatories are adequate to the proper discussion of the constantly accumulating results which such observatory is capable of turning out.

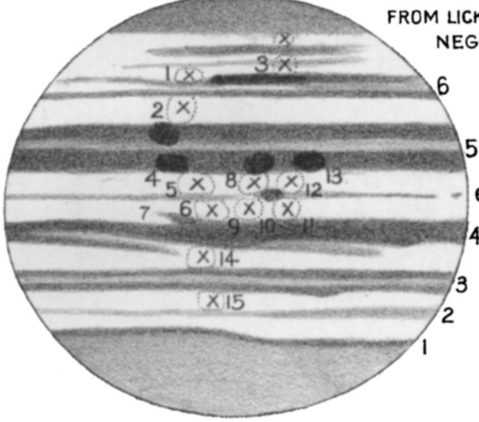
The present photographs were taken with the great refractor of the Lick Observatory, all the exposures having been made by Messrs. E. S. Holden and W. W. Campbell, and the plates having been all developed by the last named. The photographs were enlarged directly in the telescope rather more than eight times, the image of *Jupiter* on the plates measuring nearly an inch in diameter when the planet was near opposition. For further information as to the method of working, etc., reference should be made to a recent paper by Messrs. Holden and Campbell in the *Monthly Notices*, Vol. LII, page 499. It should be mentioned here, however, that one of the greatest obstacles to securing the finest results appears to lie in the presence of wind, since, to quote from the paper above mentioned, "the negatives are affected by the wind blowing on the instrument (and by other accidental disturbances) as if they were taken in the principal focus of a telescope 400 feet long."

JUPITER

1891.

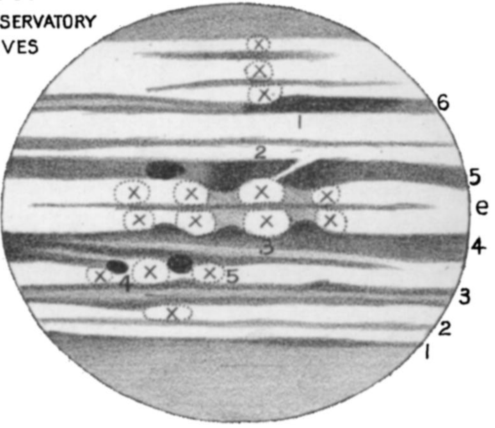
FROM LICK OBSERVATORY
NEGATIVES

FIG. 1.



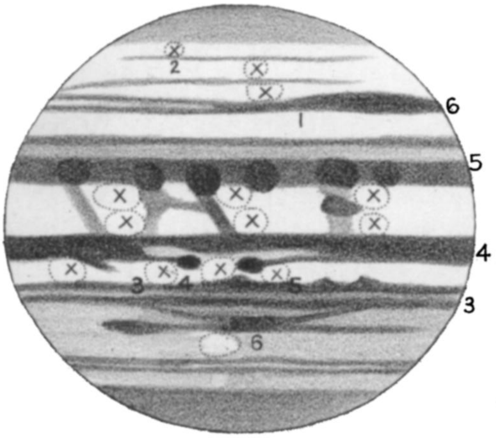
λ I. = 255°; II. = 153°.

FIG. 2.



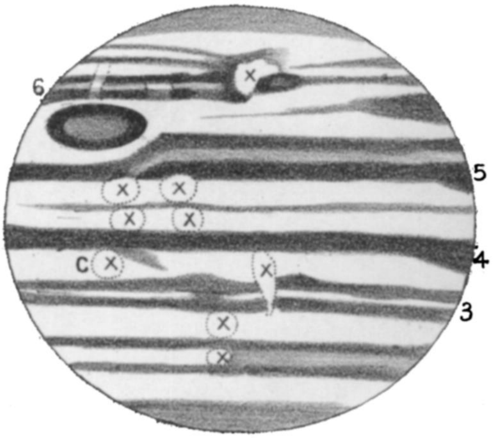
λ I. = 28°; II. = 278°.

FIG. 3.



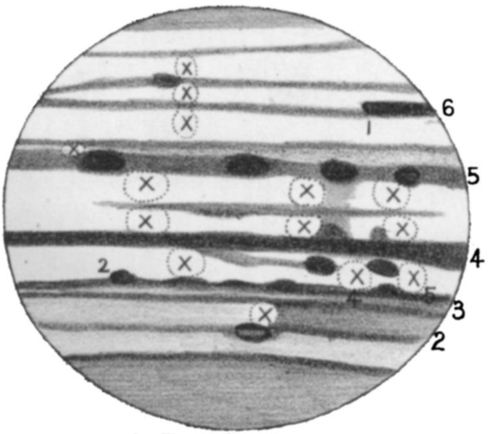
λ I. = 354°; II. = 253°.

FIG. 4.



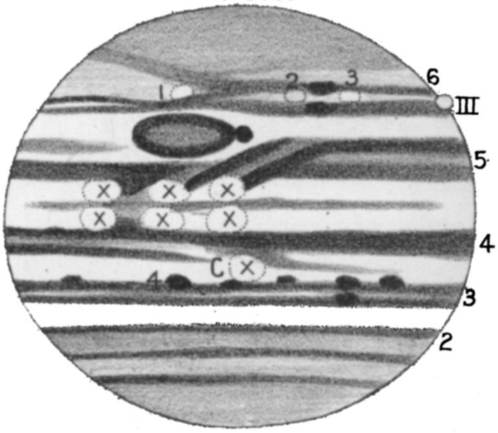
λ I. = 150°; II. = 42°.

FIG. 5.



λ I. = 68°; II. = 221°.

FIG. 6.



λ I. = 78°; II. = 20°.

A. S. WILLIAMS DEL.

The present notes are the result of a preliminary examination of the photographs. It is the writer's intention to eventually subject them to a much closer scrutiny, and to make an extensive series of measures of the positions of the different spots and belts. But the present notes will, it is conceived, serve to form a comprehensive index to these photographic records, which will be useful and available to all those who make a study of the planet; besides giving some idea of the excellence of the photographs, and of the rich amount of valuable information preserved in them. The figures which accompany this paper must not be considered in anyway as *copies* of the original photographs, or as giving a good idea of them. They have no pretensions to emulate Professor WEINEK'S beautiful drawings of the Lick lunar photographs, and they must be considered merely as diagrams or index maps to the originals. But every detail shown is present in the photographs, and with a few exceptions in a measurable form, together with many others not given.

The approximate zenographical longitudes of the central meridian of the planet's disc are given for each plate according to two systems employed by Mr. MARTH in his "Ephemeris for Physical Observations of *Jupiter*" in the *Monthly Notices.* System I relates to the markings in the equatorial zone and on the S. equatorial belt: System II serves for the remaining regions of the planet. It should be mentioned, however, that the dark spots on the south edge of belt 3 moved with exceptional velocity last year, so that their motion did not conform, even approximately, with either system of longitude. The times given are Pacific standard times. The chief belts are numbered uniformly in each figure on the outside of the disc: 3 is the double N. temperate belt; 4, the N. equatorial belt; 5, the double S. equatorial belt; 6, the double S. temperate belt. Lighter spots are indicated by a cross with a dotted outline.

In comparing these results with others, it should be recollected that the photographic image of the planet is not quite the same as the visual one. Red markings for instance, appear relatively darker on the photographs than they do in the telescope. The great red spot is thus more conspicuous in the photographs relative to other markings than it ever appeared to the writer at the same time with a 6½-inch reflector. The dark belts also usually appear narrower visually than they do photographically, probably because of the effects of irradiation produced by the adjacent bright zones being greater in the former case. The phase-darkening of the disc when the planet is near quadrature is also more evident in the photographs than in the telescope.

PLATE I. 1891, Aug. 25, 12^h 28^m long. of C. M. I = 255°; II = 153°. See fig. 1. There are four images of the planet on the plate, which is a good one. The most striking feature shown is the remarkable short red streak in the southern hemisphere which has been termed by Mr. BARNARD "the new red spot." The great intensity or depth of tone of this streak comes out very strikingly. It is much the darkest marking on the disc. The photographs reveal several interesting details in connection with it. South of the preceding end of the streak is a small bright spot, and another fainter one lies opposite in the bright zone between belts 5 and 6. They also reveal a further peculiar and very important detail. In a recent valuable paper Dr. TERBY, of Louvain, has given an interesting account of his observations of *Jupiter* in 1891,* and he there expresses the opinion that the "new red spot" cannot be considered as constituting a more obscure portion of one of the southern belts of the disc, but that on the contrary it had appeared isolated, and situated between two belts. This view, however, is contrary to the evidence afforded by the Lick photographs. In these the S. temperate belt (6) appears *distinctly double.* One component band of this double belt *is in the same parallel with the new red spot,* the other and more conspicuous one lies north of it. Hence it would appear that Dr. TERBY whilst seeing clearly the northernmost component band of this double belt, failed to distinguish the southernmost band lying in the same parallel with the new red spot. It is a new proof of the value of these photographic records when we find that they appear able to extend and even correct the observations and inferences of so practised an observer. It may be mentioned that the duplicity of belt 6 is apparent in all four images, so that there is no doubt of its existence.

In the equatorial regions of the planet various important details appear. Particularly noteworthy are, the double aspect of the great south equatorial belt, and sundry dark streaks on the N. side of the N. equatorial belt. These streaks are slightly inclined to the direction of the belts, and evidently form part of the remarkable complex structure discovered by Dr. TERBY.[*] In the light equatorial zone several brighter spots are shown distinctly, arranged in pairs. In 1891 the dark N. temperate belt 3 was the seat of great disturbance. A great number of blackish spots appeared on the S. edge of this belt, and were remarkable for the extraordinary quickness of their motion, something like 280 miles an hour relative to closely adjacent markings. In the photographs belt 3 is distinctly double, and an inclined arrangement of the streaks is apparent, which appears to support the suspicions of Dr. TERBY and the writer, from visual observations, that the belt may have had a structure analogous to that discovered by the former in the N. equatorial belt.

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* "Sur l'apparition de plusieurs nouvelles Taches Rouges dans l'hemisphere austral de *Jupiter* et sur la Structure de la Bande septentrionale 4 de cette Planète." *Bull. de l'Acad. roy. de Belgique*, t. XXII, No. 11, pp. 378-386.

PLATE II. Aug. 26, $11^h 46^m$ long. I = 28°; II = 278°. Fig. 2. The four images on this plate are also good, and show a large amount of interesting detail. The following points deserve special notice. (1) The long dark streak marked 1 on belt No. 6. Viewed through the telescope this dark streak was colored very deeply with red. The photographs show that belt 6 is double preceding the streak, which, according to visual observations, was itself double, and was clearly merely a remarkably intensified portion of the belt. (2) The S. equatorial belt 5. This is conspicuously double on the preceding part of the disc, but towards the east the southernmost component becomes gradually narrower and fainter, until it dwindles away almost to nothing. This peculiarity has existed for several years past, and has served as a convenient index by which to know that the advent of the great red spot on the disc may be expected. The northernmost band of the double belt shows many details. Perhaps the most interesting is the curious narrow light rift extending in a *sf.* direction through the belt from the brilliant equatorial spot marked 2. This light rift recalls the bright streamers described by Professor KEELER as appearing to be projected from the bright equatorial zone into the dark equatorial belts in 1889.[†]

(3) The equatorial zone is remarkable for the curious pairs of light spots, and above all for the two very prominent spots marked 2 and 3 in fig. 2. These are very conspicuous in the

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[*] See *Astr. Nach.*, No. 2928. The projecting streamer mark 7, which evidently forms part of the same structure, is only shown distinctly in one of the four photographic images.

[†] See *Publications* A. S. P., Vol. II, p. 287. The streamers in question form a portion of the complex structure of Dr. TERBY above referred to. There are a number of important points still requiring to be solved in connection with the true structure of the belts.

photographs, where they shine out almost as if they were luminous. They have also been extensively observed visually, both in the last apparition of 1891 and in the preceding one of 1890, and they are still visible. Their rate of rotation has conformed very closely in this period with that adopted by Mr. MARTH as the basis of his ephemeris "System I," but their motion has not been perfectly uniform.

(4) The N. equatorial belt. Here there are many interesting details. Particularly noticeable is the curious system of rifts or streaks forming part of TERBY'S structure already alluded to. On the N. edge of the belt are two very dark spots, and in the bright zone on the north are two very bright luminous looking spots marked 4 and 5, and a third smaller and fainter one to the left. These markings formed a very characteristic feature of the planet last year. It is a little doubtful from the photographs, on a preliminary examination whether the bright spot 5 may not break into the rift on the S. of it. In any case, however, the photographs reveal more of the real structure of this belt than do most of the published sketches of the planet.

(5) The N. temperate belt 3 is again clearly double. Between the white spots 4 and 5 is a dark projection or spot, one of those remarkable for the rapidity of their motion; and on the right is a fainter object of the same kind.

PLATE III. Sept. 28, $10^h\ 33^m$ long. I = 158°; II = 156°. The night of Sept. 28 was a very windy one, and in consequence there is a great falling off in the quality of the photographs. Spots and other details are not indeed wanting, but the outlines are ill-defined, and present a washed-out appearance very different from the sharp clean aspect which they have in the photographs taken under favorable conditions. The chief points of interest are,—

(1) The "new red spot" numbered 3 in fig. 1. The *f.* end of this spot, which is of course very prominent, is nearly on the central meridian of the disc, the little bright spot at its *p.* end being just distinguishable. Belt 6 gives the impression of being double *f.* the spot rather strongly, and its southern edge is apparently continuous with the southern edge of the "new red spot," thus confirming the indications of plate I relative to this marking being merely a greatly intensified portion of the belt.

(2) The S. equatorial belt is double, and on the northernmost component are two large and rather conspicuous dark masses. In

the equatorial zone are some faint light spots and a faint dark streak connecting the two equatorial belts.

(3) The N. equatorial belt shows several spots and irregularities, but the image is not sharp enough to clearly decipher the structure. The N. temperate belt gives feebly the impression of being double.

PLATE IV. Sept. 28, $10^h\ 42^m$ long. I = 163°; II = 162°. Having been taken only about 9^m after plate III and under similar conditions, the descriptions relating to the last photograph apply with equal force to the present case. But a little distance eastward of the central meridian there appears to be a narrow bright rift cutting right through the N. equatorial belt nearly at right angles to the direction of the belts. Also there is a conspicuous dark spot on belt 3.

PLATE V. Sept. 28, $11^h\ 54^m$ long. I = 207°; II = 205°. The photographs are again comparatively poor owing to the windy night. The N. equatorial belt is greatly enlarged on the *f.* half of the disc, this enlarged portion being the part represented in fig. 2. The N. temperate belt 3, which is double, is pushed northwards on account of this increased thickness of the N. equatorial belt. The narrow light rift referred to in the description of the last plate as cutting through the N. equatorial belt is shown more clearly than before, and appears to be a very curious feature. It lies about half way from the C. M. to the *p.* limb. Its longitude is very approximately 175° (System II). The S. equatorial belt is double, the southernmost band being much narrower than the other. Belt 6 is also distinctly double.

PLATE VI. Oct. 11, $8^h\ 59^m$ long. I = 354°; II = 253°. Fig. 3. The longitude of the central meridian (System II) is not very dissimilar from that of fig. 2 (Aug. 26), so that it is interesting and instructive to compare the photographs made on the two dates, and to note the changes which have occurred in the interval of 46 days. In the region south of the S. equatorial belt but little change has occurred. It should be noted, however, that, owing to the westerly drift of markings here, the different objects, and in particular the long intensely dark streak marked 1, have all suffered a displacement relative to the bright and dark spots on the N. side of the N. equatorial belt. The equatorial markings have made very nearly a complete revolution of the planet relative to these latter spots, so that the two bright spots, 2 and 3 of fig. 2, are identical with the two easternmost equatorial spots of fig. 3,

where they are too far from the C. M. to show with best advantage. Similarly the two spots at the centre of the disc in fig. 3 are identical with the westernmost equatorial spots of fig. 2.

On the N. side of the N. equatorial belt we find also little alteration. The two bright spots marked 4 and 5 are very conspicuous in the photographs of Oct. 11, as they are on those of Aug. 26. Spot 4 is particularly prominent.* The spot marked 3 is also a very bright one. Being nearer the C. M. it is better seen than in the photographs of Aug. 26. It seems nearly to break through into the bright rift on the S. Some change has occurred, however, in the structure of the N. equatorial belt here. The rifts are not traceable to the same extent as on the photographs of Aug. 26, whilst the bright spot 4 is clearly in connection with the easternmost rift.

But it is in the N. temperate belt 3 and the region north of it that the most considerable changes have occurred. This portion of the planet is very obscure in the photographs of Oct. 11, and the details are not easily distinguishable clearly. Hence more careful study will probably render alterations necessary in some of the minor details shown in fig. 3. The spot marked 6 is rather conspicuous, however, and it would seem that the bright spot visible to the west of it is the same as the bright spot shown in fig. 2 just on the N. side of the double belt 3, and that it may have been forced into a more northern latitude by the extension of the dark material here. On the S. edge of the double belt 3 is a conspicuous dark spot on the central meridian with two fainter ones to the east of it.

PLATE VII. Oct. 11, $10^h\ 7^m$ long. I = 35°; II = 294°. In the interval of over an hour between the exposures the markings shown in fig. 3 have all made a great stride to the westward through the rotation of the planet. The long dark streak 1 is a long way past transit. Just south of its *f.* end is a small spot of remarkable brilliancy, a noticeable object. On the *f.* limb is the great red spot.

In the equatorial zone are a number of the usual light spots. The two numbered 2 and 3 in fig. 2 are now better seen, and the former penetrates deeply into the S. equatorial belt. The complicated portion of the N. equatorial belt depicted in figs. 2 and 3 is now disappearing near the *p.* limb of the planet, and the remainder of the belt is comparatively monotonous.

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* This spot was first observed by the writer as long ago as April 10, 1887, and it has ever since continued to be an object of exceptional brilliancy. For the observations of 1887 see *Zenographical Fragments*, I, p. 32, where the spot has been named L.

On the south edge of the double belt 3 are no less than six of the curious dark projecting spots. The region northward is still very obscure, but the belts are more distinctly marked and appear to have been less disturbed.

PLATE VIII. Oct. 11, 11^h 6^m long. I = 71°; II = 330°. Owing to the rotation of the planet the great red spot is now wholly on the disc, whilst the long streak 1 of fig. 3 is on the preceding limb. The bright spot just S. of the *f.* end of the latter is very conspicuous. South and east of it can faintly be distinguished a dark shading which visually was one of the most curious objects which the writer recollects seeing on the planet: In the telescope it appeared of an oval shape and nearly as large as the great red spot, its color too being distinctly pale reddish. But the chief peculiarity consisted of an almost indescribable filmy, gauzy, wispy indefiniteness of aspect. The great red spot appears very dense in the photographs, but owing to wind having sprung up the outlines are not very sharp. Belt 6 is darker above the spot, with which it seems in contact, and is here distinctly double. In the equatorial zone are a conspicuous pair of bright spots, a little west of the central meridian, and other details; amongst them being a pair of dark streaks near the center of the disc, two dark spots on the S. equatorial belt, and two dark projections on the S. edge of the N. equatorial belt. Belt 3 is broad and dense, its duplicity being just distinguishable. On its S. edge are one or two spots.

PLATE IX. Oct. 12, 8^h 57^m long. I = 150°; II = 42°. Fig. 4. Although marked "windy" the plate is a very fine one, the images (three in number) being remarkably dense and showing much detail. In the positive copies the red spot and chief belts come out nearly black and almost opaque in some cases. The chief points of interest are,—

(1) The great red spot. This is distinctly annular, the interior being lighter, and the *p.* end appears blunter than the *f.* one, probably because it is more foreshortened. (2) Above the red spot, but separated from it by a clear interval, is belt No. 6, which is shown to be distinctly double. In the light rift of the belt are at least two brighter spots, one of which, just above the red spot, seems to extend faintly right across the double belt. Near the central meridian belt 6 is quite broken up and distorted almost

beyond recognition; the different fragments of it enclose a conspicuous brighter spot. (3) The equatorial belts. Few variations in the shape of definite spots are shown. The double character of the S. equatorial belt *f.* the red spot comes out well, however, as does also the deep hollow or bay opposite the latter. On the N. side of the N. equatorial belt is a brighter spot marked C in fig. 4. This spot is particularly notable on account of its remarkable longevity. It was first observed by Mr. DENNING, at Bristol, as long ago as Jan. 27, 1885; subsequently by Dr. TERBY, at Louvain, on March 19, 1885; and it has since been extensively observed at every successive apparition of *Jupiter* up to the present time.

(5) Belt No. 3. This appears very obscure and enormously swollen. In point of plainness it is very little inferior to the N. equatorial belt. A little east of the central meridian a curious light streak appears to cut right through the belt. The duplicity of the belt is just traceable, but it is not at all easy owing to the breadth of the component bands. The chief belts, rather curiously, all appear darker and broadened at the limbs, particularly at the *f.* limb of the planet.

PLATE X. Oct. 25, $8^h\,56^m$ long. I = 42°; II = 195°. Owing to the presence of wind the outlines of the belts are blurred and indefinite. Belt 6 is evidently double, and a little east of the central meridian are two dark spots on it, one on either component of the double belt, and nearly opposite each other. The N. equatorial belt becomes much enlarged near the *f.* limb.

PLATE XI. Oct. 25, $9^h\,39^m$ long. I = 68°; II = 221°. Fig. 5. There are three images on the plate, but as in two of them the features are very much blurred, owing to the presence of wind, most of the details shown in fig. 5 depend upon the examination of a single image, and hence it is difficult to eliminate the effects of spots and defects in the film. The chief points of interest are,—

(1) The long red spot 1 on the *f.* limb. (2) A curious row of three brighter spots west of the central meridian, the central spot being the plainest. There is an appearance as if the spots extended faintly across the two narrow dark belts, but it is not very decided. Just west of the bright spots is an obvious dark spot, which, according to Dr. TERBY, was red.

(3) The S. equatorial belt. This is curiously broken up into conspicuous dark cloudy patches, the portions of the belt between which are very feeble and apparently much encroached upon by

bright material. The southernmost component of the belt is very feeble and narrow.

(4) The N. equatorial belt. Compare this with figs. 2 and 3. The bright spots 4 and 5 are numbered alike in all three figures. In the present photograph the structure on the N. side of the belt is not very clear. The dark spots on either side of spot 4 are obvious, but the remaining dark parts are faint and indefinite, and there seems to have been a distinct fading away in the intensity of the dark material on the northern side of this belt.

(5) Belt 3. There are at least five dark spots on its southern edge. Two of these are very conspicuous, namely, the spot marked 2, and the one situated between spots 4 and 5.

(6) The dark spot on belt 2 is double, and seems to be formed chiefly by two overlapping ends of the belt where broken, but this is not quite clear. It may be mentioned here, that the two westernmost bright spots shown in the equatorial zone in fig. 5 are identical with spots 2 and 3 of fig. 2.

PLATE XII. Oct. 25, $11^h\ 17^m$ long. I = 128°; II = 280°. Although still windy, the photographs are very fair. The long red spot 1 of fig. 5 is now a little past transit, the bright spot at its *f.* end, referred to under Plate VII, being very conspicuous. The S. equatorial belt still continues very spotty and uneven. In the equatorial zone are also a number of spots and other details. Just past transit is a particularly obvious pair of bright spots. The complicated portion of the N. equatorial belt shown in fig. 5 lies near the *p.* limb, the bright spots 4 and 5 being still conspicuous, as are also the adjacent dark spots. The whole surface to the north of belt 3 is very obscure, but the belts here are less disturbed. Belt 3 itself is very broad and dark, its duplicity being just traceable.

PLATE XIII. Aug. 19, $13^h\ 51^m$ long. I = 78°; II = 20°. Fig. 6. Although last in order of consideration the present photograph is first in point of date, and is in every way a remarkably fine specimen, perhaps, indeed, the finest and most interesting photograph of *Jupiter* that has ever been obtained. The original negative is preserved at the Lick Observatory, but there is a positive copy on glass in the library of the R. A. S. Fig. 6 gives but a poor idea of the wealth of delicate details contained in this photograph. The following are some of the chief points of interest,—

(1) Belt No. 6 is very distinctly double, and *f.*, the central

meridian, is very broad. Above the red spot is a very brilliant white spot marked 1. Owing to its great brilliancy and its situation relative to the red spot this object was extensively observed last year, and it has been figured by Mr. DENNING in the *Observatory*, 1891, page 329. Its slow westerly drift relative to the red spot is well seen by a comparison of this sketch with fig. 6. Following it are two fainter spots numbered 2 and 3, situated in the rift of the double belt 6.

(2) The great red spot. This appears very distinctly annular, the interior being considerably lighter than the rest. The shadow of satellite III is projected on its *f.* end, the satellite itself being visible about half entered on the disc.

(3) The S. equatorial belt. Very remarkable, is an obvious tendency to the formation of short inclined streaks, the dark streak immediately *f.* the red spot being particularly evident. This peculiarity evidently has some relationship to a structure of the belt resembling that discovered by Dr. TERBY in the N. equatorial belt. It should be noted that these streaks are inclined in the opposite direction to those of the N. equatorial belt.

(4) The equatorial zone, which contains several rather plain bright spots. The faint dark belt in the middle is fairly plain.

(5) N. equatorial belt. On the N. side of this belt is the very remarkable bright spot C, referred to under Plate IX, the history of which dates back to January, 1885. It is very distinct in the photograph. From it a narrow bright rift extends into the N. equatorial belt, and can be traced almost up to the *p.* limb of the planet. It resembles the bright streamers observed by Professor KEELER in 1889, with the difference that instead of appearing projected from the equatorial zone into the belt, it appears as if projected from the bright extra-equatorial zone into the same belt. It evidently forms part of TERBY'S structure.

(6) Belt No. 3. The photograph shows this to be double with great distinctness. On the S. edge are six of the curious rapidly moving spots, and on its N. side a seventh dark spot.

It will be seen that fig. 6 shows twenty-four distinct spots, all of which are perfectly obvious in the photograph, where there are also many additional fainter ones and various other delicate details. The photograph evidently therefore compares favorably with the *average drawing* of *Jupiter* in point of quantity of detail, and is certainly immensely more accurate; though of course we can see visually much more minute details than can be photographed at present.